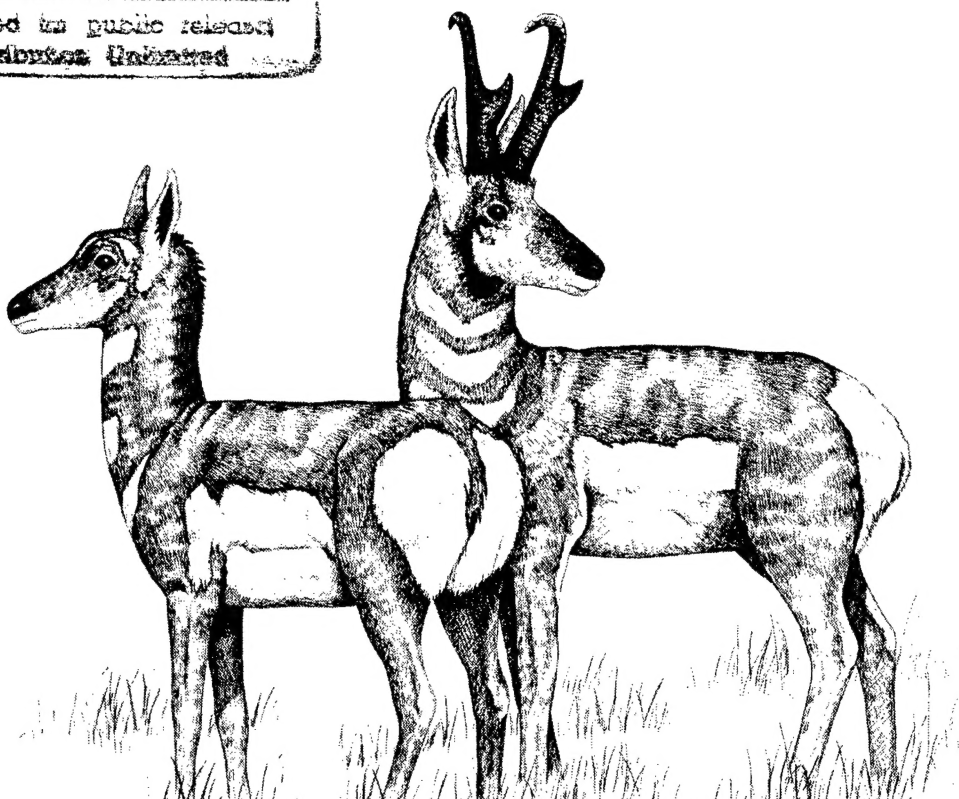
FWS/OBS-82/10.65
JUNE 1984

HABITAT SUITABILITY INDEX MODELS: PRONGHORN



Fish and Wildlife Service

U.S. Department of the Interior

MODEL EVALUATION FORM

Habitat models are designed for a wide variety of planning applications where habitat information is an important consideration in the decision process. However, it is impossible to develop a model that performs equally well in all situations. Assistance from users and researchers is an important part of the model improvement process. Each model is published individually to facilitate updating and reprinting as new information becomes available. User feedback on model performance will assist in improving habitat models for future applications. Please complete this form following application or review of the model. Feel free to include additional information that may be of use to either a model developer or model user. We also would appreciate information on model testing, modification, and application, as well as copies of modified models or test results. Please return this form to:

Habitat Evaluation Procedures Group
U.S. Fish and Wildlife Service
2627 Redwing Road, Creekside One
Fort Collins, CO 80526-2899

Thank you for your assistance.

Species ______________ Geographic Location ____________________________________

Habitat or Cover Type(s) ____

Type of Application: Impact Analysis ____ Management Action Analysis _____
Baseline _____ Other ____

Variables Measured or Evaluated ____
____
____
____

Was the species information useful and accurate? Yes ____ No ____

If not, what corrections or improvements are needed?______________________
____
____
____

Were the variables and curves clearly defined and useful? Yes ____ No ____

If not, how were or could they be improved? ______________________________

____

____

____

Were the techniques suggested for collection of field data:

Appropriate? Yes ____ No ____

Clearly defined? Yes ____ No ____

Easily applied? Yes ____ No ____

If not, what other data collection techniques are needed? _______________

____

____

____

Were the model equations logical? Yes ____ No ____

Appropriate? Yes ____ No ____

How were or could they be improved? ____________________________________

____

____

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Other suggestions for modification or improvement (attach curves, equations, graphs, or other appropriate information) ____________________

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Additional references or information that should be included in the model:

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____

Model Evaluater or Reviewer ___________________________ Date ______________

Agency ____

Address ____

____

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Telephone Number Comm: _________________________ FTS _____________________

FWS/OBS-82/10.65
June 1984

HABITAT SUITABILITY INDEX MODELS: PRONGHORN

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PREFACE

This document is part of the Habitat Suitability Index (HSI) Model Series (FWS/OBS-82/10), which provides habitat information useful for impact assessment and habitat management. Several types of habitat information are provided. The Habitat Use Information Section is largely constrained to those data that can be used to derive quantitative relationships between key environmental variables and habitat suitability. The habitat use information provides the foundation for the HSI model that follows. In addition, this same information may be useful in the development of other models more appropriate to specific assessment or evaluation needs.

The HSI Model Section documents a habitat model and information pertinent to its application. The model synthesizes the habitat use information into a framework appropriate for field application and is scaled to produce an index value between 0.0 (unsuitable habitat) and 1.0 (optimum habitat). The application information includes descriptions of the geographic ranges and seasonal application of the model, its current verification status, and a listing of model variables with recommended measurement techniques.

In essence, the model presented herein is a hypothesis of species-habitat relationships and not a statement of proven cause and effect relationships. Results of model performance tests, when available, are referenced. However, models that have demonstrated reliability in specific situations may prove unreliable in others. For this reason, feedback is encouraged from users of this model concerning improvements and other suggestions that may increase the utility and effectiveness of this habitat-based approach to fish and wildlife planning. Please send suggestions to:

Habitat Evaluation Procedures Group
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PRONGHORN (*Antilocapra americana*)

HABITAT USE INFORMATION

General

The pronghorn (*Antilocapra americana*) is commonly found in association with grasslands and sagebrush (*Artemisia* spp.) communities. In 1964, 62% of North American pronghorn were associated with grasslands (41% shortgrass, 21% mixed), 37% were on grassland-brushland [33% bunchgrass-sagebrush, 3% galleta (*Hilaria* spp.)-woodland, 1% grama (*Bouteloua* spp.)-mesquite (*Prosopis* spp.)] and 1% were associated with deserts (Yoakum 1972). The highest densities of pronghorn occur on rangelands with an annual precipitation rate of 25.4 to 38.1 cm (10.0 to 15.0 inches) (Autenrieth 1978).

Food

Foods utilized by pronghorn vary seasonally depending upon the availability, palatability and succulence of vegetation (Hoover et al. 1959). Vegetation consumed includes practically all available species although there is a high preference for more succulent forage (Yoakum 1978). Pronghorn will move from relatively dry ranges to more mesic sites in search of succulent vegetation. When forbs are scarce, pronghorn select the most succulent alternative browse available (Beale and Smith 1970).

The average annual diet of pronghorn in the short grass plains region of Colorado was approximately 43% forbs, 40% browse, 11% cacti (*Opuntia* spp.), and 6% grass (Hoover 1966). Cole and Wilkins (1958) presented data suggesting similar annual dietary trends for pronghorn on grama-needlegrass-wheatgrass (*Bouteloua*-*Stipa*-*Agropyron*) cover types in central Montana. However, Severson et al. (1980) reported annual diets of 5% forbs, 3% graminoids, and over 90% browse for sagebrush-grass ranges in central Wyoming. These data suggest variable food habits dependent on availability throughout the range of pronghorn.

Considering only food habits, ranges dominated by approximately equal proportions of forbs and browse, with some cacti and grasses, would provide the highest carrying capacity for pronghorn (Hoover 1966). However, Yoakum (1974) stated that the most important factor influencing high population density antelope ranges in the Great Basin was that the range be in approximately 50% food production, consisting of approximately 40 to 60% grass, 10 to 30% forbs, and 5 to 10% in browse.

Browse was the most heavily utilized winter food by pronghorn in Alberta even though its availability was extremely limited (Mitchell 1980). Browse accounted for more than 90% of the winter diet of pronghorn in Utah (Beale and Smith 1970), 93% of the winter diet in Montana (Bayless 1969) and 71.6% and 54.2% of the fall and winter diet, respectively, in Colorado (Hoover 1966). Sagebrush, rabbitbrush (*Chrysothamnus* spp.), and bitterbrush (*Purshia tridentata*) were identified as particularly important pronghorn forage in the Great Basin (Yoakum 1982). Big sagebrush (*A. tridentata*), bitterbrush, and saltbush (*Atriplex* spp.) were important pronghorn winter forage plants in Montana (Bayless 1969). Black sagebrush (*A. nova*) was the most important source of browse on pronghorn winter range in Utah (Beale and Smith 1970). Other important species were winterfat (*Ceratoides lanata*), brickellia (*Brickellia* spp.), and Douglas rabbitbrush (*C. viscidiflorus*).

Habitats dominated by sagebrush have often been reported to be a key component of northern pronghorn ranges (Dirschl 1963; Martinka 1967; Bayless 1969; Beale and Smith 1970; Barrett 1980). Pronghorn populations in Alberta with access to winter ranges containing concentrations of sagebrush were more stable than herds which inhabited ranges supporting lesser amounts of sagebrush (Barrett and Vriend 1980). Dirschl (1963) indicated that abundance of shrubs was a prime factor determining carrying capacity of winter ranges.

Spring is the only time of year when grasses appear to comprise a significant portion of the pronghorn's diet (Hoover 1966; Beale and Smith 1970). The high protein content of early spring growth in grasses (Cook and Harris 1952; Fierro 1977) may be particularly beneficial to pronghorn at a time when other forage species are of poor quality (Wallmo et al. 1977). Grass is also consumed during green-up periods in warm weather (Bayless 1969). Grasses other than wheat (*Triticum aestivum*) were found to be a relatively unimportant component of the pronghorn's diet in Kansas (Sexton et al. 1981). Pronghorn in Utah were not observed to use dry, mature grass at any time (Beale and Smith 1970).

Wheat was a major constant (74%) of the November through April diet of pronghorn living in the vicinity of green wheat fields in Colorado (Hoover 1966). At least 60% of the pronghorn diet in Kansas from October through March was wheat (Sexton et al. 1981). The proportion of wheat in the diet decreased to 1.7% by April. Pronghorn concentrated where they had access to cropland and native vegetation during severe winter weather in Alberta (Mitchell 1980), but did not consistently winter in areas which contained more than 25% of the land area in cultivation (Barrett 1980). Sexton et al. (1981) reported that pronghorn in Kansas inhabited areas consisting of up to 30% agricultural land. The amount of use of grain fields is dependent on their proximity to native rangelands (Cole and Wilkins 1958). Grain fields in Montana less than 0.8 km (0.5 mi) from native rangelands received greater use by antelope, during all seasons of the year, than did fields more than 0.8 km from rangelands.

Water

Water is a critical component of pronghorn ranges during summer and fall. Pronghorn will drink water daily if it is available (Einarsen 1948). Ranges which produce and maintain high pronghorn densities have water available every 1.6 to 8.0 km (1.0 to 5.0 mi) (Yoakum 1974). Sundstrom (1968) observed 95% of over 12,000 pronghorn in Wyoming within a 4.8 to 6.4 km (3.0 to 4.0 mi) radius from water. The maximum distance from pronghorn kidding sites in Alberta to open water was less than 4.0 km (2.5 mi) (Barrett 1981), but the mean distance was only 586 ± 31 m (641 ± 34 yd).

Water consumption by pronghorn has been reported to be inversely related to the succulence of available forage (Beale and Smith 1970). Pronghorn were not observed drinking water when forbs with a high moisture content were abundant.

Pronghorn in Colorado were reluctant to drink from stock tanks; however, they did drink overflow water (Hoover et al. 1959). Autenrieth (1978) reported that pronghorn will utilize most facilities designed for livestock watering and that such facilities should remain useable throughout the summer and fall on northern ranges and year-round on southern ranges. Where natural water is limited or absent, development of water sources may encourage better distribution of pronghorn.

Winter water requirements are often assumed to be provided by snow, but unfrozen water sources may be important on ranges when snow is absent. Guenzel et al. (1982) found that pronghorn distributions were strongly affected by an unfrozen water source during a relatively snow-free winter in south-central Wyoming. Wyoming Game and Fish Department employees noted water stress in pronghorns in areas with frequently long, snow-free periods in winter (Cook 1984). These areas received only about 0.7 cm (0.3 inches) of precipitation per month in the winter.

Cover

Pronghorn typically inhabit land forms characterized by low rolling, expansive terrain (Autenrieth 1978). Pronghorn were never observed for more than a few minutes at a time where their view was restricted by terrain or other natural features (Prenzlow et al. 1968). Kindschy et al. (1982) felt that areas with less than 5% slope were optimum for pronghorn.

Microhabitats provided by topographic relief apparently increase habitat quality during winter. Montana pronghorn selected microhabitats with more favorable conditions during winter (e.g., lower wind velocities, less snow, less dense snow), than the average for the whole area (Bruns 1977). During the fall and winter pronghorn spent more time in basins ≥ 1.6 km (1 mi) in diameter than at other times of the year in Colorado (Prenzlow et al. 1968). Amstrup (1978) occasionally observed pronghorn on slopes of 50% or more, but only 7% of all observations were on slopes exceeding 20%. However, pronghorn in Colorado did not move to sheltered environments such as groves of trees, haystacks or large rocks, or into canyons during storms (Prenzlow et al. 1968).

Topographic variation may also increase the probability that snow-free foraging areas exist during winter. Pronghorn often frequent areas of reduced snow accumulations (e.g., edges of ditches, creek beds, the lee side of thick stands of sagebrush) for foraging during winter (Bruns 1977). When normal winter feeding areas become snow-covered, pronghorn move to steeper windswept areas where vegetation is more exposed (Einarsen 1948). Martinka (1967) reported pronghorn dying of malnutrition during a severe winter when excessive snow depths prohibited the use of coulees and restricted the animals to a grassland type. Only minor losses occurred on winter ranges where big sagebrush and silver sagebrush (A. cana) were available on southern exposures and windblown ridges. Winter concentrations of pronghorn in Alberta were often observed in, and adjacent to, breaks and coulees which provided protection from the wind, and increased availability of shrubs (Mitchell 1980). These herds were sedentary for weeks at a time where microhabitats provided food and shelter. Most pronghorn winter ranges in Alberta were associated with drainage systems containing abundant sagebrush (Barrett and Vriend 1980). High winds, in areas of high topographic diversity, act to maintain snow-free feeding sites, even in relatively severe winters (Ryder 1983).

Vegetation provides cover for many large ungulates, but tall, dense vegetation is of minimal value to pronghorn because of both limited visibility and mobility. Rangelands with an average vegetation height of 61 cm (24 inches) were less preferred than ranges averaging 38 cm (15 inches) (Yoakum 1978). Ranges supporting vegetation averaging 76 cm (30 inches) in height were rarely used by pronghorn.

Reproduction

Einarsen (1948) described traditional pronghorn fawning areas in terms of terrain characteristics and vegetation height. Optimal fawning grounds were characterized as being situated in a basin, surrounded by a low ridge of hills, where standing vegetation averaged 22.8 to 45.7 cm (9.0 to 18.0 inches) in height. Although certain topographical and plant features appeared to contribute to preferred parturition sites in Alberta, Barrett (1981) reported no evidence indicating the existence of traditional fawning areas. Habitat diversity provided by silver sagebrush, small depressions, and stands of forbs and grasses 25.0 cm (9.8 inches) or taller, contributed to above average fawn survival. Eighty-eight percent of the pronghorn fawns captured in the shortgrass prairie region of Colorado were located in the vicinity of washouts, taller grass, or rocks (Prenzlow et al. 1968). Vegetation at daytime sites, where pronghorn fawns less than 4 weeks of age were observed, was taller than the vegetation in the surrounding area (Tucker and Garner 1980). No significant differences were noted between fawn-site vegetation and the height of vegetation in the surrounding area for fawns older than 4 weeks.

Interspersion

Pronghorn home range size is dependent upon topography, the presence of physical barriers, and the amount of forage available in the area (Bayless 1969). The area required depends upon the range having all of the habitat requirements in sufficient quality and quantity for all seasons of the year

(Yoakum 1974). The geographic location and size of home ranges change throughout the year in a rhythmic pattern (Buechner 1950). The winter range may include an area as large as 6.4 by 9.6 km (4.0 by 6.0 mi). Pronghorn in Wyoming remained on an area of 2.6 to 5.2 km^2 (1.0 to 2.0 mi^2) during the summer and early fall, although daily movements covered from 0.2 to 0.6 km^2 (0.07 to 0.23 mi^2) (Gregg 1955 cited by O'Gara 1978). Pronghorn in Alberta remained relatively sedentary on their summer range and exhibited strong fidelity for their natal range (Mitchell 1980).

The timing and length of movements of pronghorn vary with altitude, latitude, weather and range conditions (Yoakum 1978). Movements are directly related to seeking the basic habitat requirements of water and forage. Differentiation of summer and winter ranges has been reported to be determined by snow depth (Autenrieth 1978; Yoakum 1978). Pronghorn in Saskatchewan regularly avoided areas where snow exceeded 18 cm (7 inches) in depth (Pyle 1972 cited by Mitchell 1980). Bruns (1977) stated that pronghorn may be "opportunistic migrants" because herds may not migrate to definite wintering areas each year. Pronghorn are believed to undertake migration only if forced to do so as a result of extreme weather or habitat conditions. Such movements would cease when more favorable habitat was reached, or a change occurred in climatic conditions. The arrival and persistence of inclement weather during the late fall prompted pronghorn in Alberta to move from the more open summer and fall ranges to topographically diverse areas adjacent to water courses (Mitchell 1980). Fall migration of Idaho pronghorn to winter ranges may not be initiated by snow depth or storms, but rather by a decreased moisture content of forage on higher elevation ranges (Hoskinson and Tester 1980). However, snow depth was reported to influence the geographic location of winter ranges, and the initiation and rate of movement back to the summer range. Bayless (1969) reported that 50% of the antelope for which home ranges were calculated were observed to "shift" home ranges. Such movements were defined as movement from the original area of activity to another area with no subsequent return to the original area. The size of pronghorn home and seasonal ranges is a result of habitat conditions and the influences of weather, thus, home range data for the species seldom has application to other areas, or even to the same range from year to year (O'Gara 1978).

Special Considerations

Compatibility of antelope and livestock is related to the number of animals using the same range, season of use, and forage condition (Autenrieth 1978). Based on dietary overlaps during the year, horses, cattle, and sheep in Wyoming's Red Desert were similar in their food preferences, whereas antelope food habits were dissimilar to those of domestic livestock (Olsen and Hansen 1977).

Because the diets of cattle and pronghorn are sufficiently different during the fall and winter there is little competition for forage (Salwasser 1980). Competition for spring grasses and forbs may result if heavy cattle grazing occurs on pronghorn ranges prior to mid-May. Cattle also may compete with pronghorn if heavy grazing is allowed on meadows within the summer range. Cattle can have a positive impact on pronghorn habitats if their early summer

use of grasses favors the maintenance of annual forbs on spring and summer ranges. Pronghorn in Texas do well on overgrazed cattle ranges because forbs increase under such grazing conditions; however, sheep competed directly with pronghorn by removing many palatable forbs (O'Gara 1978).

Sheep have the highest potential for dietary overlap and competition with pronghorn (Severson et al. 1968; Salwasser 1980). Pronghorn abandoned a Montana range used by sheep (Campbell 1970 cited by O'Gara 1978). Salwasser (1980) recommended: 1) pronghorn winter ranges should not be grazed by sheep to the extent that significant use of browse occurs; 2) sheep should be excluded from spring ranges until pronghorn have moved onto their summer range; and 3) sheep should not be turned out on summer range until pronghorn fawning is completed.

Fences on pronghorn ranges may restrict movements and can be a direct cause of injury or mortality (Rouse 1962; Yoakum 1978; Salwasser 1980). Fences may have significant impacts when constructed in migration routes or where they interfere with daily movements to and from water or feeding areas (Salwasser 1980; Yoakum 1980). Pronghorn exhibit some adaptability to crawl under, go through, or jump fences as the type of construction permits (Rouse 1962). There is a general concensus among pronghorn biologists that the species usually will not jump over fences (Salwasser 1980). Citing BLM Manual 1737 (Bureau of Land Management 1975), Salwasser (1980) made the following recommendations concerning fence construction: (1) fences on cattle ranges should be constructed of three strands, with the top strand no higher than 97 cm (38 inches); the bottom wire should be barbless, and at least 41 cm (16 inches) above the ground; and (2) fences on sheep ranges should be constructed of four strands with the highest strand not exceeding 81 cm (32 inches) in height; the bottom wire should be barbless and at least 25 cm (10 inches) above the ground.

HABITAT SUITABILITY INDEX (HSI) MODEL

Model Applicability

Geographic area. This model has been developed chiefly for application from the Great Basin to and including the Great Plains. Model assumptions will be most realistic in regions where severe winter weather influences pronghorn population characteristics. However, the model is probably applicable for habitat evaluation throughout the historic range of *A. a. americana* (range: Great Plains of the United States and Canada, and the Great Basin). This model is not applicable for habitat evaluation for *A. a. mexicana* (range: isolated areas of southern Arizona, New Mexico, Texas, and Mexico), *A. a. peninsularis* (range: Baja California, Mexico), or *A. a. sonorienses* (range: extreme southern Arizona to west-central Mexico). Figure 1 illustrates the approximate geographic area for which this model is applicable.

Season. This model is applicable for the evaluation of pronghorn winter range.

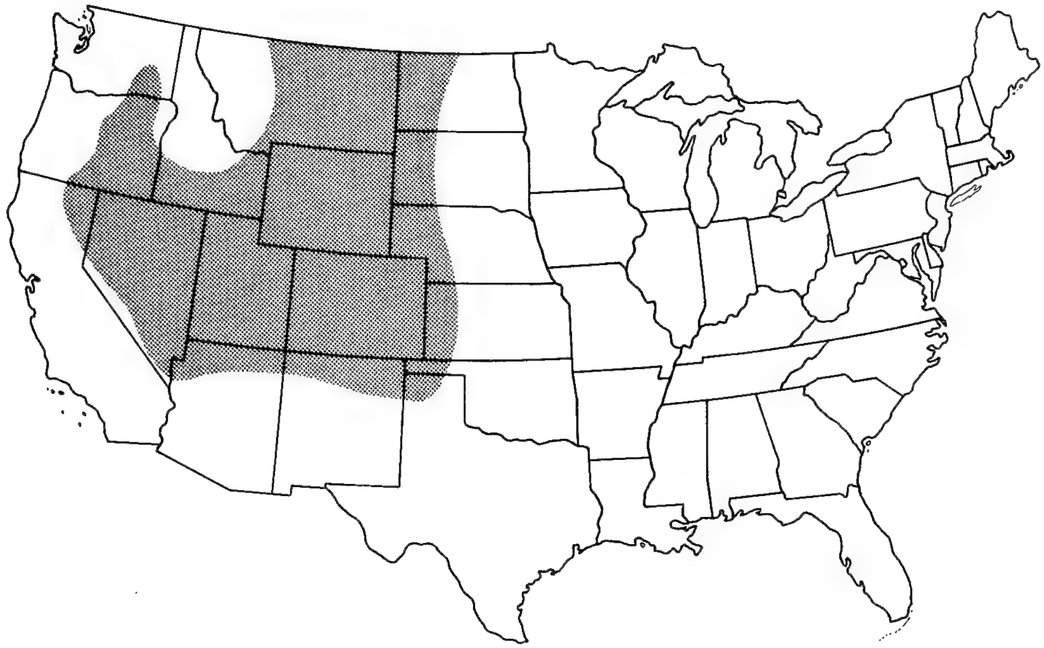


Figure 1. Approximate geographic area of applicability for the pronghorn HSI model.

Cover types. This model was developed to evaluate habitat quality in the following cover types (terminology follows that of U.S. Fish and Wildlife Service 1981): Evergreen Shrubland (ES); Deciduous Shrubland (DS); Evergreen Shrub Savanna (ESS); Deciduous Shrub Savanna (DSS); Grassland (G); Forbland (F); and Cropland (C).

Minimum habitat area. Minimum habitat area is defined as the minimum amount of contiguous habitat that is required before an area will be utilized by a species. The majority of pronghorn in North America now exist on ranges which vary from 8 to 16 km (5 to 10 mi) in diameter (Yoakum 1978). However, the minimum winter range area for pronghorn was not reported in the literature. Several winter ranges used to evaluate the performance of this model (Cook 1984) were less than 30 km^2 (11.8 mi^2) in area. Based on this information it is assumed that an area must provide a minimum of 30.0 km^2 (11.8 mi^2) of contiguous habitat before it will be suitable as pronghorn winter range. A 30.0 km^2 (11.8 mi^2) circle has a radius of 3.1 km (1.2 mi).

Verification level. A draft of this model was evaluated against pronghorn population densities on 29 winter ranges in Colorado, Idaho, Montana, and Wyoming (Cook et al. in press). After minor modifications in variable relationships, data analysis indicated that the model addressed important habitat variables and explained 70% ($P < 0.0001$) of the variation in pronghorn

densities on the winter ranges evaluated. The current model contains the modifications and improvements in variable relationships suggested during analysis of the draft model.

Model Description

Overview. This model assumes that winter habitat characteristics are the most limiting conditions affecting pronghorn distribution and abundance. We have developed this model based on the assumptions that pronghorn survival and reproductive success are functions of winter food availability. Snow depth and duration directly affect food availability on northern winter ranges. The model attempts to characterize vegetation and topographic features favoring food availability under mild to normal snow conditions. The model assumed that snow will be available to meet pronghorn winter water requirements (see Special consideration component).

The following sections provide documentation of the logic and assumptions used to translate information on pronghorn habitat use to the variables and equations used in the HSI model. Specifically, these sections cover: (1) identification of habitat related variables; (2) definition and justification of the suitability levels of each variable; and (3) descriptions of the assumed relationships between variables.

Winter food component. Pronghorn food habits vary on a regional and local basis. The availability of adequate food is a critical winter life requisite for the pronghorn in many areas of its geographic range. Forbs commonly comprise the major portion of the pronghorn's diet when evaluated on an annual basis. Utilization of browse typically exceeds that of forbs during the winter months. It is assumed that adequate spring/summer food will never be more limiting to a pronghorn population than the quality and quantity of a winter food source. This model has been developed chiefly for areas where winter snow storms may have a major influence on habitat use and pronghorn survival. Pronghorn populations inhabiting the southerly portions of the continent may not be as dependent upon browse as a winter food source as are northern populations.

Winter food characteristics of pronghorn habitat are assumed to be a function of: (1) percent shrub crown closure; (2) the average height of the shrub canopy; (3) the number of shrub species present; (4) percent herbaceous canopy cover; and (4) to a limited degree the amount of available habitat in winter wheat. The assumed relationships between shrub crown closure, shrub height, shrub species diversity, and suitability index values for pronghorn winter food quality are presented in Figure 2.

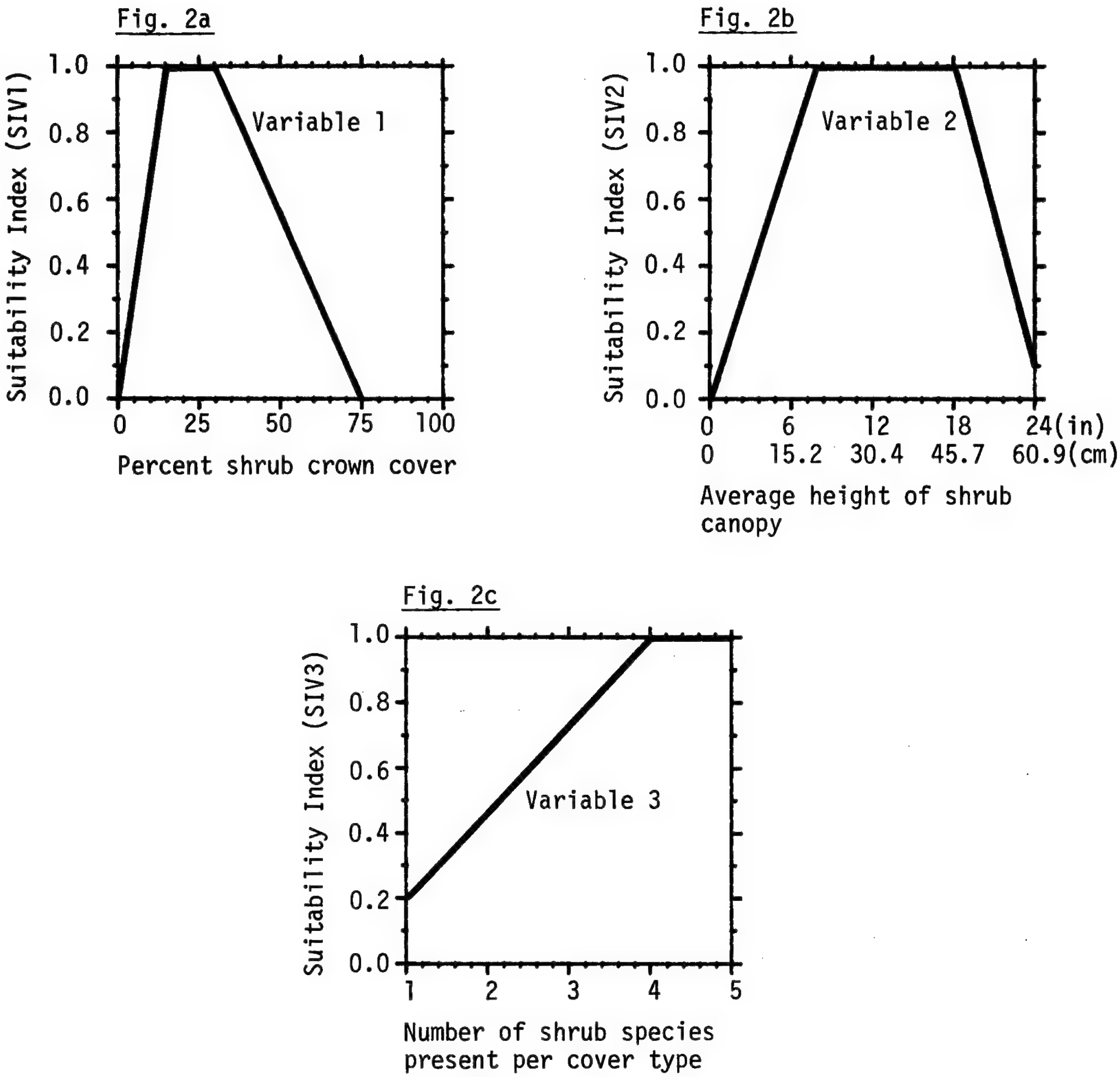


Figure 2. The relationships between shrub habitat variables and suitability index (SI) values for pronghorn winter food quality.

An optimum winter food value for pronghorn is, in part, represented when the percent shrub crown closure ranges from 15 to 30% (Fig. 2a), and the average height of the shrub canopy ranges from 20 to 46 cm (8 to 18 inches) (Fig. 2b). A shrub density and average shrub height exceeding 30% and 46 cm (18 inches), respectively, are assumed to indicate less desirable habitat quality due to interference with pronghorn mobility. Shrub cover ≥ 75% is assumed to reflect unsuitable habitat conditions, regardless of average canopy height. Average shrub height < 20 cm (8 inches) is assumed to represent less desirable habitat quality due to decreased accessibility when snow is present (Cook 1984).

The number of shrub species present (Fig. 2c) is also assumed to influence an area's potential to provide a high quality winter food source. Cover types containing four or more shrub species are assumed to represent optimum conditions. Homogeneous stands composed of only one species are assumed to have lower potential in providing an adequate winter food source.

The abundance of herbaceous vegetation and availability of winter wheat also are assumed to have an influence on the quality of a winter food source for the pronghorn. Figure 3 displays the assumed relationships between herbaceous canopy cover and the availability of winter wheat, and suitability index values for pronghorn winter food quality.

The presence of forbs and graminoids, in addition to shrubs, will often provide maximum forage diversity. Figure 3a displays the assumed relationship between the amount of herbaceous vegetation (graminoids plus forbs) present and a suitability index for winter food. Optimum conditions are assumed to exist when the herbaceous canopy coverage ranges from 10 to 40%. Herbaceous vegetative density above and below the assumed optimum conditions will result in lower SI values. Determination of a winter food value for pronghorn is chiefly a function of shrub density, therefore the complete absence of herbaceous vegetation will result in a lower food index value but will not totally limit an area's winter food potential. Sites dominated completely by herbaceous vegetation, 100% canopy closure, are assumed to have relatively low potential for providing adequate pronghorn winter food.

Winter wheat in the vicinity of, or interspersed with, rangeland is assumed to improve the winter food value for pronghorn if shrubs are present at a density of 75% crown cover or less. Figure 3b displays the relationship between the proportion of available habitat in winter wheat and a winter food suitability index for the species. Optimum winter food may be obtained if winter wheat is totally absent when shrub density and height are within optimum ranges. It is assumed that optimum amount of winter wheat will range between 5 and 25% of the evaluation area. As the percent of the evaluation area in winter wheat (including fallow) increases above 25%, habitat quality for pronghorn is assumed to decrease. Evaluation areas consisting of ≥ 50% winter wheat are assumed to provide no increased potential as winter food due to decreased availability of shrub food sources.

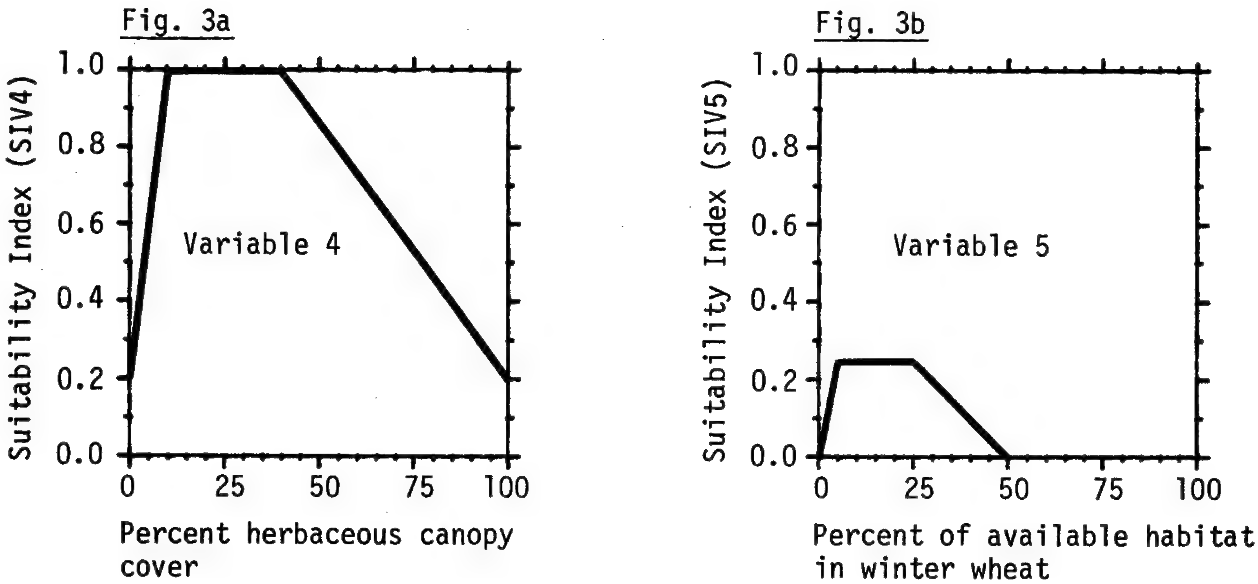


Figure 3. The relationships between herbaceous canopy cover and the amount of available habitat in winter wheat to suitability index (SI) values for pronghorn winter food quality.

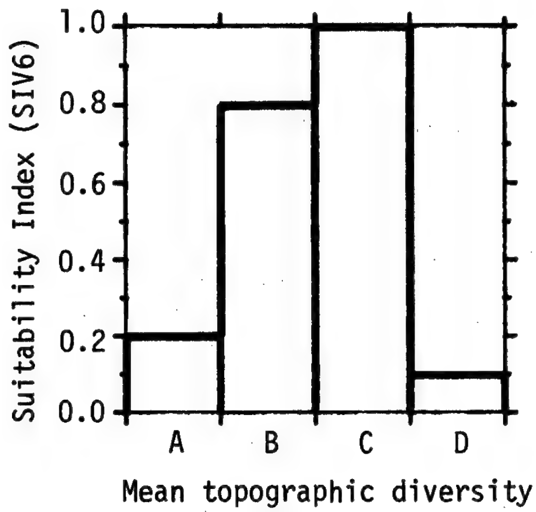
The relationships between index values calculated using the curves presented in Figures 2 and 3 are illustrated in Equation 1. Guidance for use of the model in study areas that consist of more than one cover type is provided in the Application of the Model section.

$$WFI = [V_1 \times (V_2 \times V_3 \times V_4)^{1/3}] + V_5 \qquad (1)$$

The density of shrubs, mean height of the shrub canopy, number of shrub species present, percent herbaceous canopy cover and the percent of the evaluation area in winter wheat all function to define a winter food value for the pronghorn. Percent shrub crown cover (SIV_1) has the greatest influence in determination of a winter food value in the above equation. The values calculated for average shrub canopy height (SIV_2), number of shrub species present (SIV_3), and percent herbaceous canopy closure (SIV_4) are assumed to be equal in their value for the determination of a winter food value. The geometric mean of these three SI values has a direct influence on the SI value calculated for SIV_1, percent shrub crown cover. The percent of available pronghorn habitat in winter wheat (SIV_5) may serve to slightly increase the SI value calculated for naturally occurring vegetation. However, the structure of equation 1 permits an optimum value to be obtained in the complete absence of winter wheat.

Cover component. Pronghorns typically inhabit ranges which are characterized as being expansive and low rolling. Ridges, rims, and depressions are used as thermal and escape cover and may contribute to greater diversity in food resources and foraging areas. Figure 4 displays the assumed relationships between mean topographic diversity and a cover index (CI) for the pronghorn.

Flat terrain is assumed to have a relatively low value for providing suitable winter cover conditions. Diverse terrain comprised of rolling topography, or ridges and rims, is assumed to provide high quality winter cover. Steep, broken, or mountainous terrain is assumed to have minimum potential as suitable winter cover for the species.



A) 0-2% slope; flat or nearly so
B) 3-8% slope; gently rolling
C) 9-25% slope; substantial drainages, ridges, and/or rims present
D) > 25% slope; mountainous

Figure 4. The relationship between mean topographic diversity and cover index value for pronghorn winter range.

Application of this model requires that a winter food/cover value be determined by combining the cover and winter food index values. Equation 2 is used to calculate the combined winter food/cover index (WFCI) for the pronghorn.

$$WFCI = \frac{WFI + CI}{2} \qquad (2)$$

The winter food index and cover index are assumed to have equal value in determining the overall winter food/cover index value for the pronghorn.

Model Relationships

HSI determination. The calculation of a Habitat Suitability Index for the pronghorn considers the life requisite values obtained for winter food/cover (equation 2). The HSI is equal to the winter food/cover value.

Summary of model variables. Six habitat variables are used in this model to determine winter food/cover life requisite values for the pronghorn. The relationships between habitat variables, the winter food/cover index, cover types, and an HSI value are summarized in Figure 5.

Application of the Model

We recommend determining canopy cover of vegetation classes using the line intercept method. This method is relatively accurate, especially for shrubs (Pieper 1978). Model variables are calibrated based partially on data collected using this method. Other sampling techniques may produce markedly different cover estimates.

Cook (1984) separated half shrubs and true shrubs, and combined the former class with estimates of herbaceous canopy closure, during field testing of the model. Half shrubs are defined as species generally less than 15 cm (6 inches) in height, and which die back to a woody base each year. Examples of half shrubs include fringed sagewort (*A. frigida*) and saltsage (*Atriplex nuttallii*) (Table 1). Half shrubs were treated in this manner because it is assumed that their growth form and dormancy pattern more closely simulates the availability of forbs and graminoids in winter, than that of true shrubs.

Figure 6 provides variable definitions and suggested measurement techniques (Hays et al. 1981).

This model may be used to determine HSI values for evaluation areas comprised of one cover type or for areas comprised of several cover types. In situations where two or more noncropland cover types are present within the evaluation area an overall weighted HSI (weighted by area) can be determined by performing the following steps:

1. Stratify the evaluation area into cover types.

2. Determine the area of each cover type and the total area of the evaluation area.

3. Determine SI values for all variables except V_5, percent of available habitat in winter wheat, for each noncropland cover type in the evaluation area. If present, determine the proportion of the evaluation area comprised of fallow and planted winter wheat fields (V_5). Variables other than V_5 and V_6 do not require measurement in cropland cover types.

4. Determine a WFI value for each noncropland cover type using the SI values derived in step 3 and equation 1, excluding V_5.

5. Multiply the area of each cover type by its respective WFI value, sum these products, and divide the sum by the total area of all cover types including areas planted to winter wheat. Then add the SI value for V_5 (percent of available habitat planted to winter wheat) to determine the weighted WFI.

6. Determine a cover index (CI) value for each cover type, including croplands using Figure 4.

7. Multiply the area of each cover type by its respective CI value, sum these products, and divide the sum by the total area of all cover types to obtain the weighted CI value.

8. The HSI value is determined by averaging the WFI and CI values. The steps outlined above are expressed by the following equations:

$$\text{weighted WFI} = \frac{\sum_{i=1}^{n} WFI_i A_i}{\sum_{i=1}^{n} A_i} + \text{SI value of } V_5$$

where n = number of cover types

WFI_i = winter food index value of individual noncropland cover type

A_i = area of cover type i

$$\text{weighted CI} = \frac{\sum_{i=1}^{n} CI_i A_i}{\sum_{i=1}^{n} A_i}$$

where n = number of cover types

CI_i = cover index value derived from Figure 4 for each cover type

A_i = area of cover type i

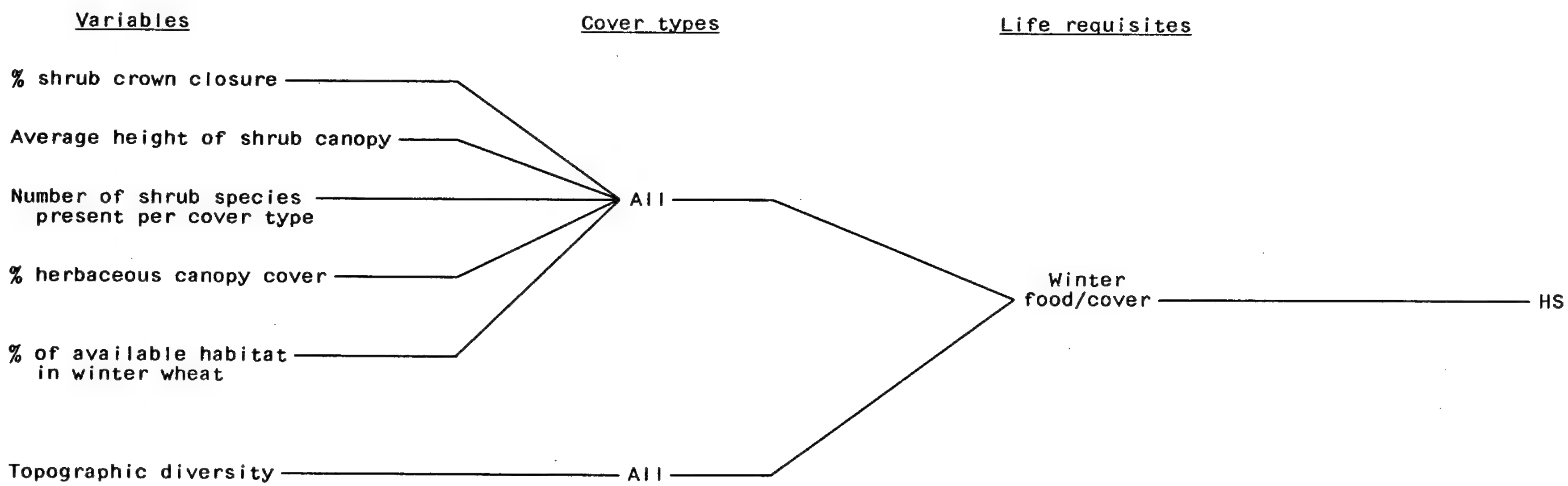


Figure 5. Relationships of habitat variables, life requisites, and cover types to the HSI for pronghorn winter range.

Table 1. Shrubs and half-shrubs encountered on 29 pronghorn winter ranges used to evaluate HSI model performance (Cook 1984).

Scientific name	Common name
Shrubs:	
Artemisia arbuscula	Low sagebrush
Artemisia cana	Silver sagebrush
Artemisia filifolia	Sand sagebrush
Artemisia longiloba	Alkali sagebrush
Artemisia nova	Black sagebrush
Artemisia tridentata tridentata	Basin big sagebrush
Artemisia tridentata vaseyana	Mountain big sagebrush
Artemisia tridentata wyomingensis	Wyoming big sagebrush
Atriplex confertifolia	Shadscale
Chrysothamnus nauseosus	Rubber rabbitbrush
Chrysothamnus viscidiflorus	Douglas rabbitbrush
Grayia spinosa	Spiny hopsage
Purshia tridentata	Antelope bitterbrush
Rhus trilobata	Skunkbush
Sarcobatus vermiculatus	Black greasewood
Symphoricarpos spp.	Snowberry
Tetradymia canescens	Gray horsebrush
Tetradymia spinosa	Catclaw horsebrush
Half-shrubs:[a]	
Artemisia frigida	Fringed sagewort
Artemisia pedatifida	Birdfoot sagebrush
Artemisia spinescens	Bud sagebrush
Atriplex nuttallii	Saltsage
Ceratoides lanata	Winterfat
Chrysothamnus greenei	Rabbitbrush
Gutierrezia sarothrae	Broom snakeweed
Kochia americana	Red sage
Tanacetum nuttallii	Chicken sage

[a]All half-shrubs listed were classified as either subshrubs or woody-based perennials by either Dorn (1977), or Hitchcock and Cronquist (1976), except C. *greenei* which was not specifically classified.

Variable (definition)		Cover types	Suggested technique
V_1	Percent shrub crown closure [the percent of the ground that is shaded by a vertical projection of the canopies of woody vegetation ≤ 5 m (16.5 ft) in height].	ES,DS,ESS,DSS, G,F	Line intercept
V_2	Average height of shrub canopy [the average vertical distance from the ground to the highest point of all woody plants ≤ 5 m (16.5 ft) tall].	ES,DS,ESS,DSS, G,F	Line intercept, graduated rod
V_3	Number of shrub species present per cover type [a tally of individual shrub species that are present at ≥ 1% canopy closure, (woody vegetation ≤ 5 m (16.5 ft) in height) encountered within each specific cover type sampled].	ES,DS,ESS,DSS, G,F	Line intercept
V_4	Percent herbaceous canopy cover [the percent of the ground surface that is shaded by a vertical projection of all nonwoody vegetation (grass, forbs, sedge, etc.)].	ES,DS,ESS,DSS, G,F	Line intercept
V_5	Percent of available habitat in winter wheat (the proportion of the evaluation area considered to be potential pronghorn habitat that is devoted to the production of winter wheat).	C	Remote sensing, on-site inspection
V_6	Topographic diversity [an appraisal of land surface structure (see variable for category descriptions)].	ES,DS,ESS,DSS, G,F,C	Remote sensing, topographic maps

Figure 6. Definitions of variables and suggested measurement techniques.

Special consideration component. Fences on pronghorn ranges may restrict movements and may have significant impacts if they obstruct migration routes. It is assumed that fences constructed of woven wire, or four or more strands of barbed wire, with bottom strand less than 25.4 cm (10.0 inches) above the ground will have the most impact on pronghorn movements. It is also assumed that if the study area is fenced into allotments ≤ 2.59 km^2 (1.0 mi^2) pronghorn movements will be hindered. If either of the above situations exist within the study area, then the Suitability Index for winter food/cover life requisite value should be decreased by one-half. If fences occur infrequently, or meet the quality described in the Special Considerations portion of the Habitat Use Information section of this model, little to no detrimental impact is assumed to occur.

Available water is a mandatory requirement for ranges to be of optimum value. Pronghorn will utilize naturally occurring water sources, stockponds, or livestock watering devices if unfrozen. Winter water requirements are normally met by snowfall; however, the availability of water during snow-free periods may influence pronghorn distribution and habitat use on some ranges. Insufficient data exist to develop a variable reflecting habitat suitability as a function of the interaction of unfrozen water sources and winter precipitation. However, unfrozen water sources may be crucial in areas receiving less than 1.0 cm (0.4 inches) of precipitation per winter month (Cook et al. in press). Model ratings of habitat quality may be suspect (i.e., too high) in low precipitation areas which lack available, free water in winter. We assume that three evenly-spaced open water sources per 100 km^2 (39 mi^2) are required by pronghorn on ranges routinely experiencing extended snow-free periods.

Snow distribution and accumulation are assumed to also influence forage availability on northern winter ranges. However, we do not fully understand the causal relationships involved. This model was evaluated using field data from wintering areas known to be consistently used by pronghorn in mild to normal snowfall winters, and population estimates obtained in mild to normal winters. Therefore, technically speaking, the model's ability to rate the value of pronghorn winter ranges during severe snow conditions has not been evaluated. We have attempted to partially address the issue of severe snow conditions through a treatment of topographic diversity. Areas which support a combination of windblown ridges with short shrubs, and drainages with dense, tall shrubs evidently provide a variety of foraging opportunities for pronghorn regardless of weather conditions (King 1979 in Cook 1984; Ryder 1983). Other factors, such as southern aspects also may be important during severe snow conditions (Martinka 1967). Users should be aware that there may be other factors, not addressed in this model, which affect the value of winter ranges for pronghorn use during severe snow conditions.

SOURCES OF OTHER MODELS

Kindschy et al. (1982) provide evaluation criteria and a work sheet for rating pronghorn habitat potential in the Great Basin.

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16. Abstract (Limit: 200 words)

This is one of a series of publications that provide information on the habitat requirements of selected fish and wildlife species. Literature describing the relationship between habitat variables related to life requisites and habitat suitability for the pronghorn (Antilocapra americana) are synthesized. These data are subsequently used to develop Habitat Suitability Index (HSI) models. The HSI models are designed to provide information that can be used in impact assessment and habitat management.

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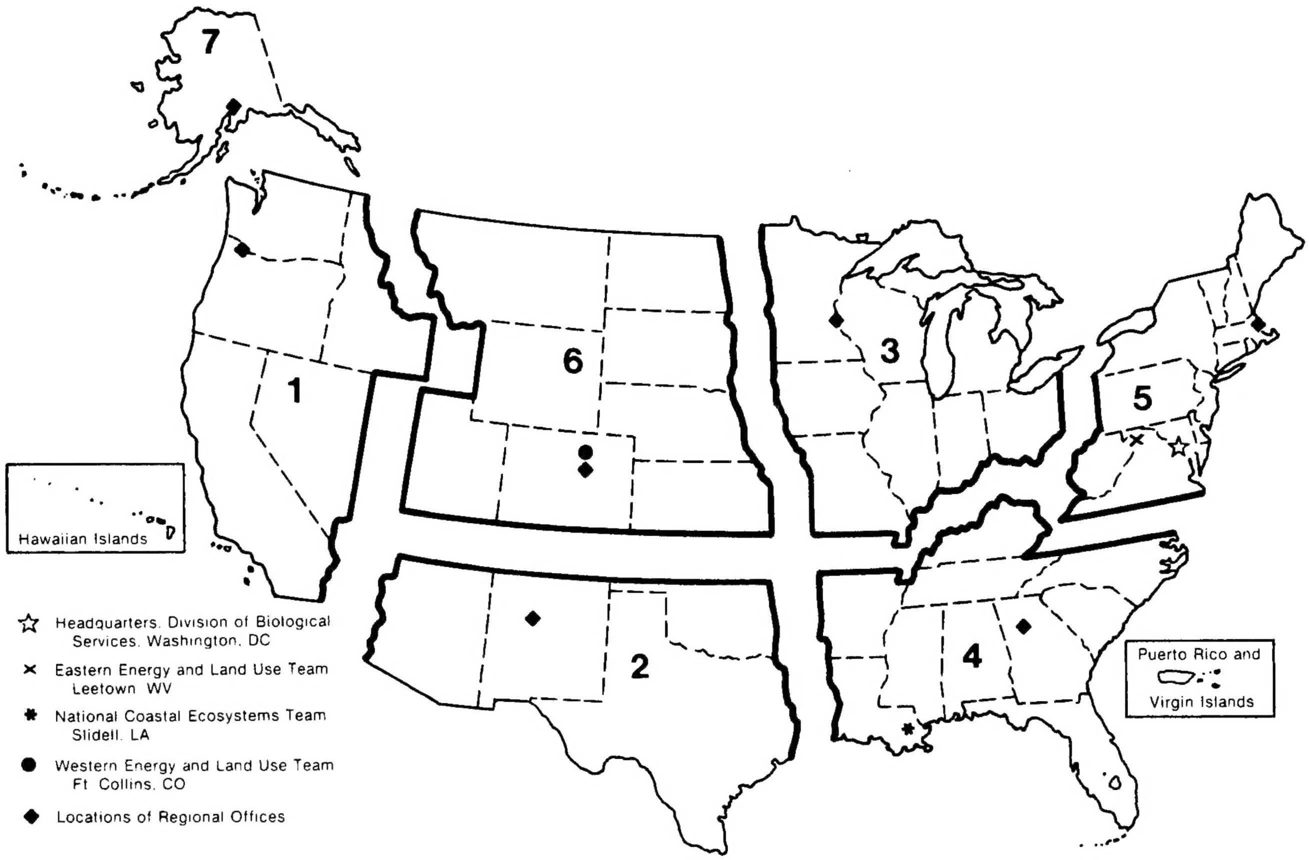

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